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Technology Collaboration Programme

Task 39
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Feedstock-to-biofuel(s) supply chain analysis

Focus on CAPEX and OPEX cost reduction opportunities for advanced biofuels

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Feedstock Availability in India

Crop wise area, total dry biomass, surplus biomass, and bioethanol production potential of selected crops in India (Reference: TIFAC 2018 report)

Crop	Area (Mha)	Dry Biomass (MMT)	Surplus biomass (MMT)	Bioethanol Potential (BL)
Rice	44.360	225.487	43.856	12.017
Wheat	30.838	145.449	25.070	6.919
Maize	8.781	27.880	6.036	1.346
Sugarcane	5.037	119.169	41.559	14.629
Gram	8.484	26.515	8.724	2.172
Tur	4.113	9.167	1.755	0.446
Soyabean	10.694	27.779	9.950	2.935
Rapeseed & Mustard	5.869	17.085	5.157	1.495
Cotton	12.158	66.583	29.740	7.405
Ground Nut	5.474	12.900	3.873	0.848
Castor	1.185	4.604	3.017	1.134
All Crops across all seasons	136.994	682.618	178.738	51.348

✓51 billion litre of 2G ethanol potential

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Biomass availability at USA

Feedstock	2017	2022	2030	2040
	Million dry tons			
Currently used resources				
Forestry resources	154	154	154	154
Agricultural resources	144	144	144	144
Waste resources	68	68	68	68
Total currently used	**365**	**365**	**365**	**365**
Potential: Base-case scenario				
Forestry resources (all timberland)[a, b]	103	109	97	97
Forestry resources (no federal timberland)[a, b]	84	88	77	80
Agricultural residues	104	123	149	176
Energy crops[c]		78	239	411
Waste resources[d]	137	139	140	142
Total base-case scenario potential (all timberland)	**343**	**449**	**625**	**826**
Total base-case scenario (currently used + potential)	***709***	***814***	***991***	***1,192***
Potential: High-yield scenario				
Forestry resources (all timberland)[b, e]	95	99	87	76
Forestry resources (no federal timberland)[b, e]	78	81	71	66
Agricultural residues	105	135	174	200
Energy crops[c,f]		110	380	736
Waste resources[d]	137	139	140	142
Total high-yield scenario potential (all timberland)	**337**	**483**	**782**	**1,154**
Total high-yield scenario (currently used + potential)	***702***	***848***	***1,147***	***1,520***

~343 million tons of biomass is available as per US DOE report which, might increase to ~736 million tons by 2040

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Pretreatment technologies and process schemes

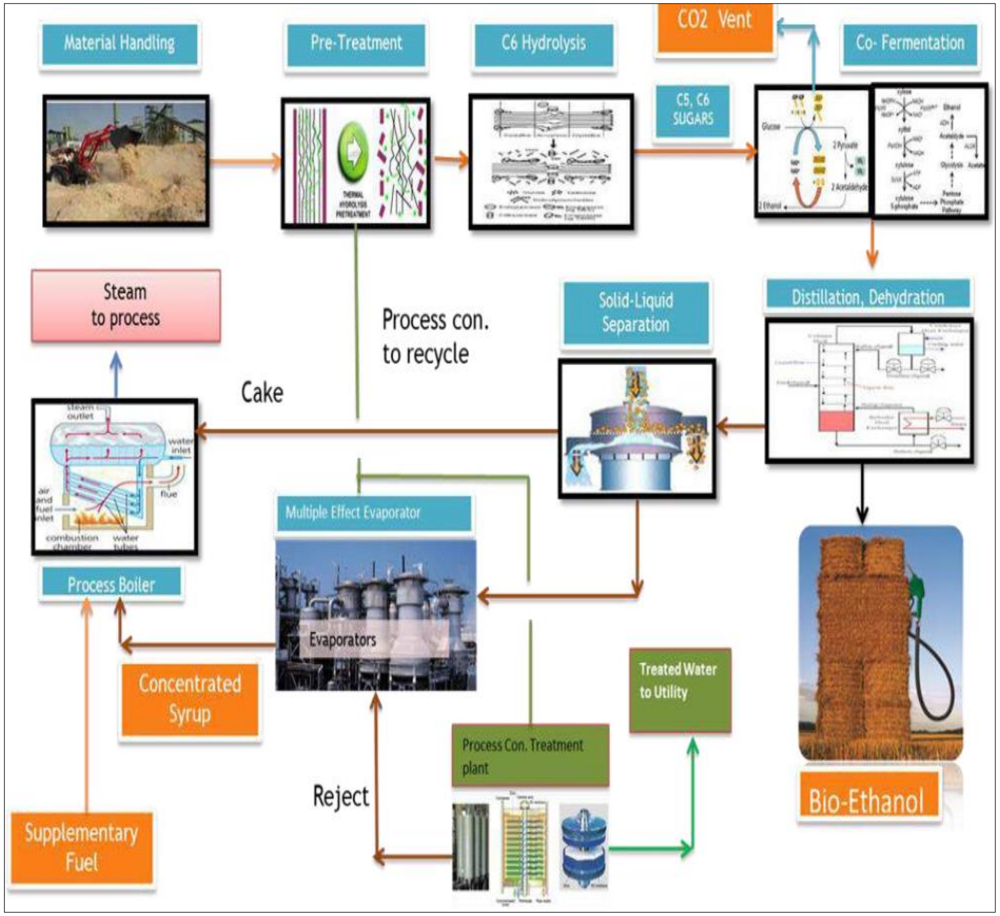


Figure 1. Process scheme of 425 TPD commercial ethanol technology developed by Praj Industries at Indian Oil commercial plant, Haryana

2G Ethanol technologies:

India
Praj Technology
DBT-ICT Technology
DBT-IOC technology

Germany
Clariant 2G ethanol plant

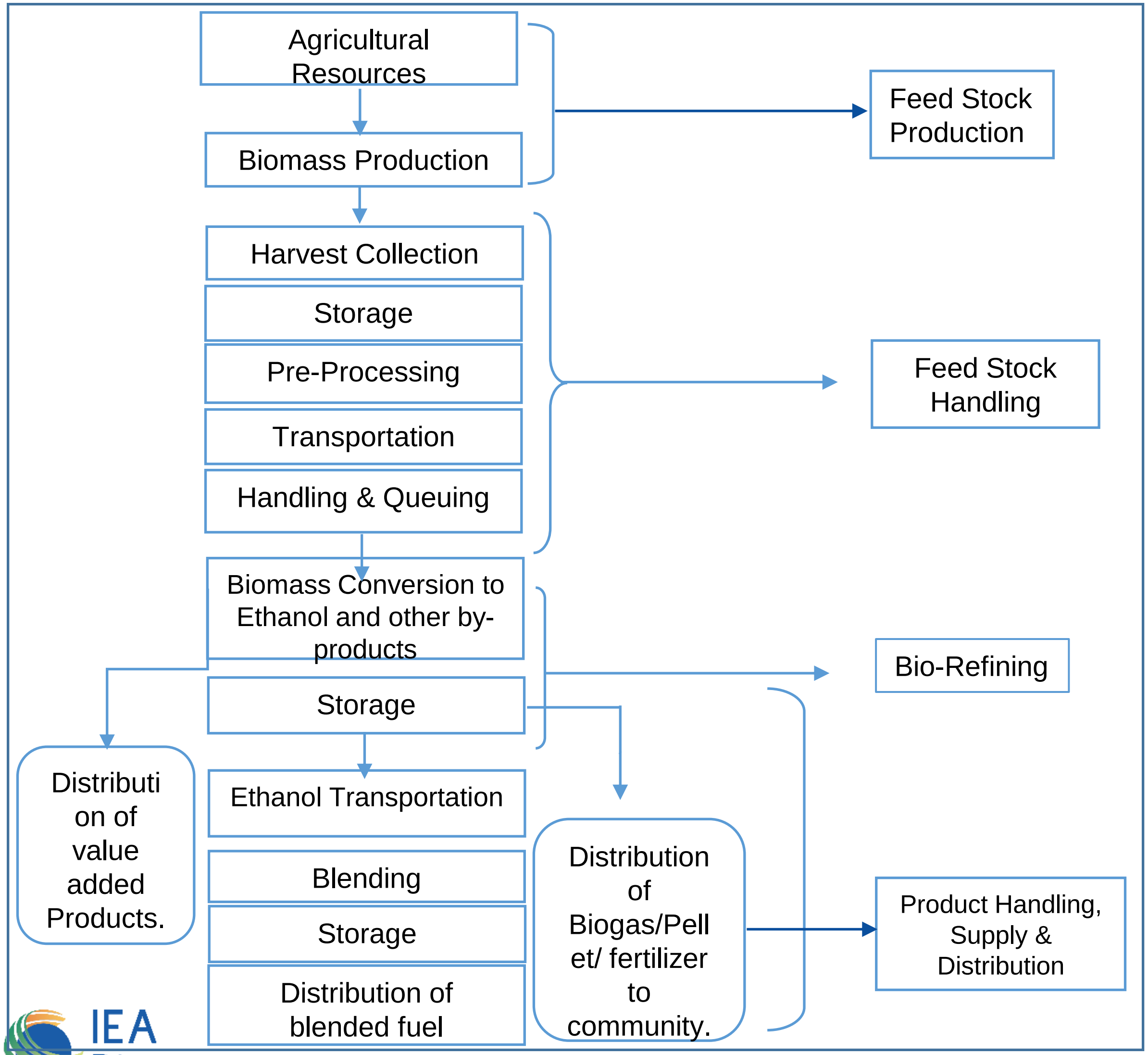
USA
Dupont, Poet-DSM. Abengoa

Brazil
Raízen Energia, Costa Pinto São Paulo, Brazil
Gran Bio and Beta Renewables Alagoas, Brazil

Centro de Tecnologia Canaviera (CTC)-Piracicaba, Brazil

Biomass supply chain approaches prevalent in India

Process depicting the typical biomass supply chain analysis



- The value chain activities can be broadly classified as:
  - ✓ Biomass/Feedstock Production
  - ✓ Feedstock Handling
  - ✓ Bio-refining and Product Handling
  - ✓ Supply & Distribution

Challenges in Feed-stock for Bio Ethanol

Challenges in feed stock for Bio Ethanol

- No **Accurate data** on Biomass availability (crop wise & District wise)
- **Collection & Densification** of Biomass
- **Transportation & Storage** of Biomass
- **Cost & Quality** of Biomass
- **Long time commitment** by Biomass Producer

- Biomass supply is critical to lignocelluloses based ethanol project which needs to be addressed well before the commencement of any commercial project
- For ensuring uninterrupted supply of biomass over a longer period at an optimal price, investors should consider various aspects of biomass production and supply chain management.

❖**Development of sustainable feedstock supply chain is critical for 2G bioethanol production**

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Models of Feedstock Supply Chain

Key features of different supply chain models are discussed

Supply Chain Model	Key Features
Model-I : Local supply through bio mass producers	▪ Direct contract with bio mass growers ▪ Sowing of the crop may be regularized by ethanol producing company like in case of sugar cane. ▪ The entire downstream related risk to be borne by the investors.
Model II - Supply through the Aggregator/ Organizer	▪ Creating mediators like cooperatives /NGO'S etc. for aggregation and possible densification or processing of biomass. ▪ Decentralized Primary biomass collection centre may be created by the company. ▪ Investors in upstream of the value chain may participate for ensuring consistent biomass supply. ▪ Extensive community participation in biomass collection and densification.
Model-III -Producer Organisation	▪ Producer organizations/co-operatives is formed by a group of producers for either farm or non-farm activities. ▪ Producers are shareholders in the organization. ▪ It deals with business activities related to the primary produce/product.
❖ **Models Applied in Rural India for Agri-produced Logistics evaluated** (ITC E-Choupal, Amul Model, PRESPL (Punjab Renewable Energy Systems Private Limited), Food Security Army, Kerala, Producer Organization- SAFAL(NDDB)	

Life cycle analysis & Environmental impact assessment

- Life cycle analysis with a focus on Indian subcontinent in particular with the Indian specific feedstocks & pretreatment technologies were evaluated
- Actual experimental inventory data collected in the pilot scale facility commissioned at Indian Oil R&D Centre was used

- Two different pretreatment approaches (dilute acid & steam explosion) were evaluated for the Greenhouse gas (GHG) emissions, net energy ratio (NER) and net energy balance (NEB).

Life cycle analysis & Environmental impact assessment

S.No.	Salient features	Steam explosion pretreatment	Dilute acid pretreatment
1	GHG emissions (kg CO2 eq.)	292	288
2	Avoided GHG emissions (kg CO2 eq.)	-246	-208
3	GHG emission reductions of 100% ethanol with respect to gasoline process (%)	~90	~80
4	Energy consumption (MJ)	1378	1736
5	Net energy balance (MJ/L)	16.3	14.9
6	Net energy ratio	2.7	2.3

LCA assessment of steam explosion and dilute acid pretreatments for the production of bioethanol from rice straw on 1 Metric Ton basis (Reference: Soam et al. (2016)

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Life cycle analysis & Environmental impact assessment

S.No.	Salient features	Dilute acid pretreatment	Extractive removal by biomass soaking in water (60ºC, 1 h) followed by dilute acid pretreatment			
		CP	MP1	MP2	MP3	MP4
1	Alkali addition (in %)	Nil	Nil	0.2	0.4	0.5
2	Acid addition (in %)	1	1	1	1.1	1.1
3	Ethanol yields (L/ton)	218	242	256	262	267
4	Global Warming Potential ($kgCO_2eq./L$)	-0.42	-0.58	-0.47	-0.32	-0.26
5	Eutrophication Potential ($kgPO_4eq./L$)	$0.2*10^{-3}$	$0.7*10^{-4}$	$0.3*10^{-3}$	$0.3*10^{-3}$	$0.4*10^{-3}$
6	Acidification potential ($kgSO_2eq./L$)	$-5.9*10^{-3}$	$-6.8*10^{-3}$	$5.6*10^{-3}$	$-4.9*10^{-3}$	$-4.5*10^{-3}$
7	Photochemical oxidant creation potential ($kgC_2H_4eq./L$	-0.1	-0.1	0.1	0.4	0.5

LCA of extractives removal pre-procedure for dilute acid pretreatment of rice straw (Reference: Soam et al. (2018))

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Life cycle analysis &

Environmental impact assessment (USA & Brazil Inputs)

Life Cycle Analysis inputs from USA

- Argonne National Laboratory showed that enzymes and yeast together contribute 1.4 and 27 % of farm-to-pump GHG emissions for corn and cellulosic ethanol, respectively.
- Relative to petroleum gasoline, ethanol from corn, sugarcane, corn stover, switchgrass and miscanthus could reduce the life-cycle GHG emissions by 19–48%, 40–62%, 90–103%, 77–97% and 101–115%, respectively.
- All sorghum based ethanol processes could reduce the WTW GHG emissions by 35% in contrast to gasoline

Life Cycle Analysis inputs from Brazil

- 1G process is more detrimental to the environment amongst all the parameters examined, except for the photochemical oxidation (PO).
- The major factor responsible for the high PO in the case of the 1G-2G process is the use of the cellulolytic enzymes.

Summary/Key Findings

- The availability, chemical composition, supply chain models, pretreatment technologies scale up at demonstration and commercial levels for key biomass was surveyed.
- Feedstock availability, capital cost, and production cost are the key challenges towards sustainable and commercial production & implementation of 2G ethanol technology
- In India, most agri-businesses falter in performance in medium to long term due to failure to address issues of raw material availability. Entrepreneurs/investors looking at establishing 2nd Gen bioethanol plants could consider steady availability of required quantities of cellulosic raw materials at predictable price ranges as one of their top priorities. It would be a good strategy if they invest on a supply chain business comprising procurement/collection, aggregation, baling and storage prior to their investment in the bioethanol plants. This would give them first hand knowledge of the challenges involved and improve the confidence levels of their bankers and stake holders as well.
- In India, some of the established supply chain model such as **ITC E-Choupal Model, Amul Model, NDDB Safal model** applied in Rural India for Agri-produced Logistics have been designed to tackle the challenges posed by the unique features of Indian agriculture, characterised by fragmented farms, weak infrastructure and the involvement of numerous intermediaries. Such type of model may be applied for Biomass supply chain management.
- Life cycle analysis & environmental impact assessment to identify the GHG emissions and energy consumption hotspots during the lignocellulosic bioethanol production process conducted.
- Production of cellulolytic enzymes and its application during enzymatic hydrolysis is a hotspot to reduce the GHG emissions.

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Thank you

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